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Mars Exploration Rover

MER Flight System Status

Athena Science Team/MER PSG Meeting - June 2002

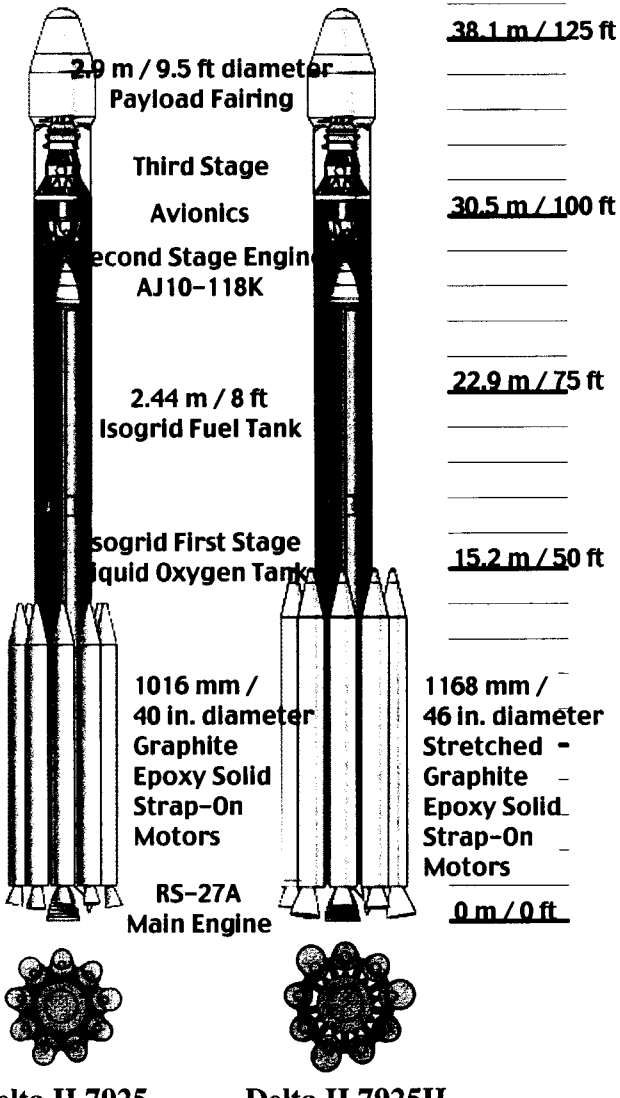
J. Matijevic

6/10/02

Outline

- System Overview
  - Launch/Cruise
  - EDL (Entry, Descent and Landing)
  - Egress
  - Surface
- What's new...
  - Subsystems :
    - Ti tanks
    - DIMES (Descent Image Motion Estimation System)
    - Solar Arrays
    - Thermal (no LHP (loop heat pipe))
    - Telecom (one Petal Low Gain Antenna (PLGA))
  - Software
- Surface Operation
- ATLO (Assembly Test and Launch Operations)
- Schedule to ship (follow the vehicles)

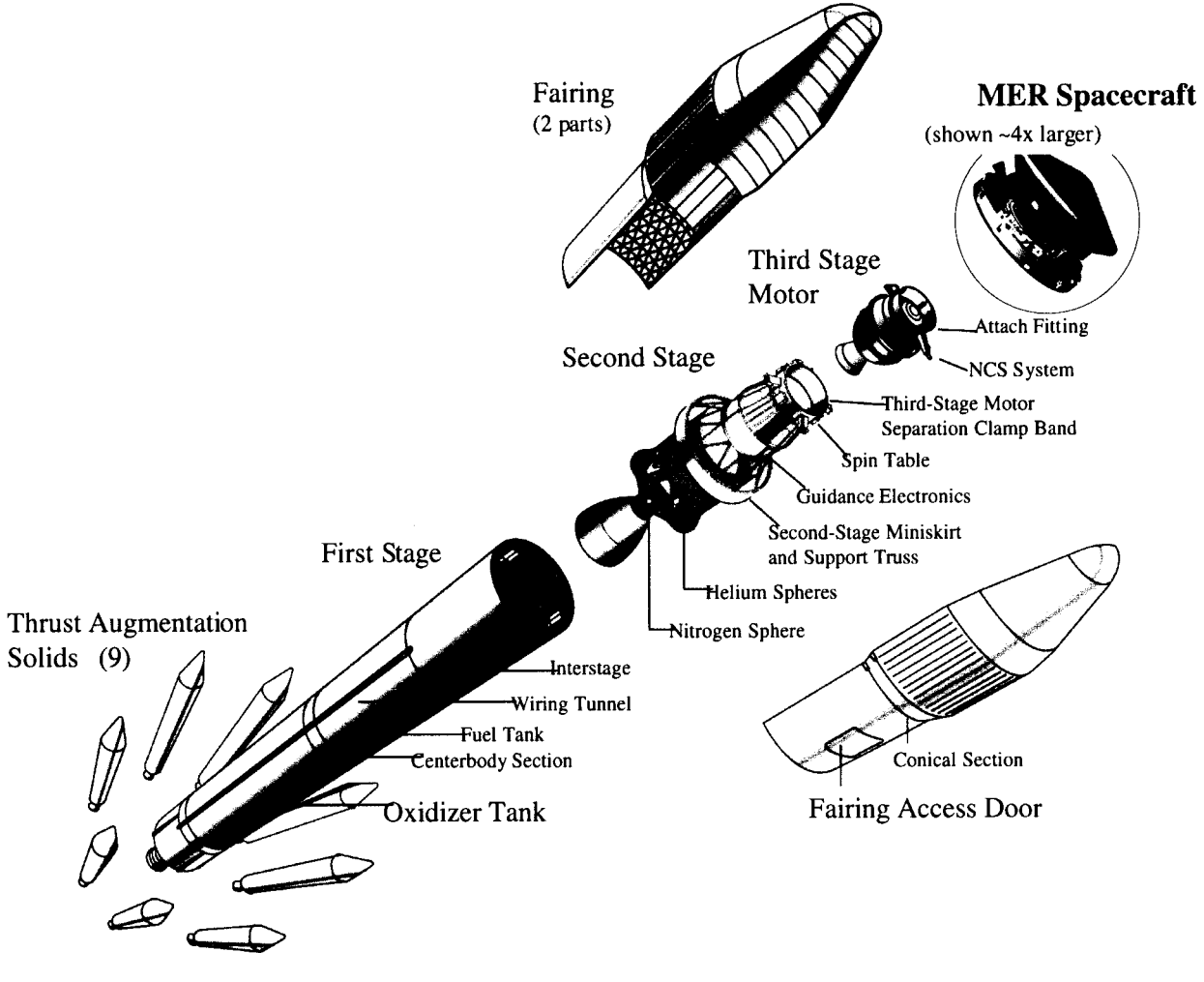
Launch



Delta II 7925 **Delta II 7925H**

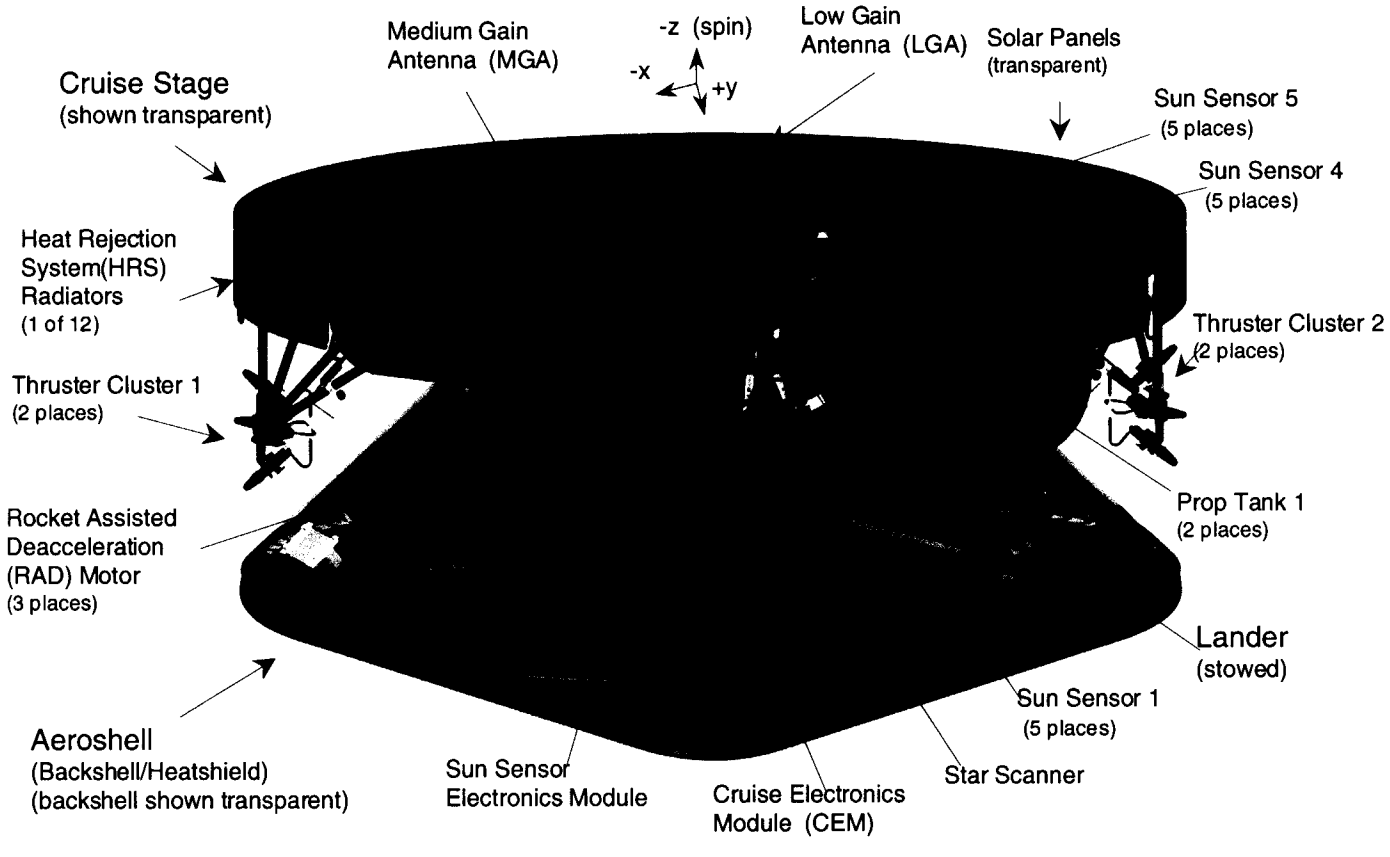
- **MER-A**
  - **Launch period : 5/30/03 - 6/16/03**
  - **Launch vehicle : Delta II 7925**
  - **Arrival date : 1/4/04**
  - **Arrival + 90 sols : 4/6/04**
- **MER-B**
  - **Launch period : 6/25/03 - 7/12/03**
  - **Launch vehicle : Delta II 7925H**
  - **Arrival date : 1/25/04**
  - **Arrival + 90 sols : 4/27/04**

Separation


Fairing
(2 parts)
MER Spacecraft
(shown ~4x larger)
Third Stage
Motor
Attach Fitting
NCS System
Second Stage
Third-Stage Motor
Separation Clamp Band
Spin Table
Guidance Electronics
Second-Stage Miniskirt
and Support Truss
Helium Spheres
Nitrogen Sphere
First Stage
Thrust Augmentation
Solids (9)
Interstage
Wiring Tunnel
Fuel Tank
Centerbody Section
Oxidizer Tank
Conical Section
Fairing Access Door

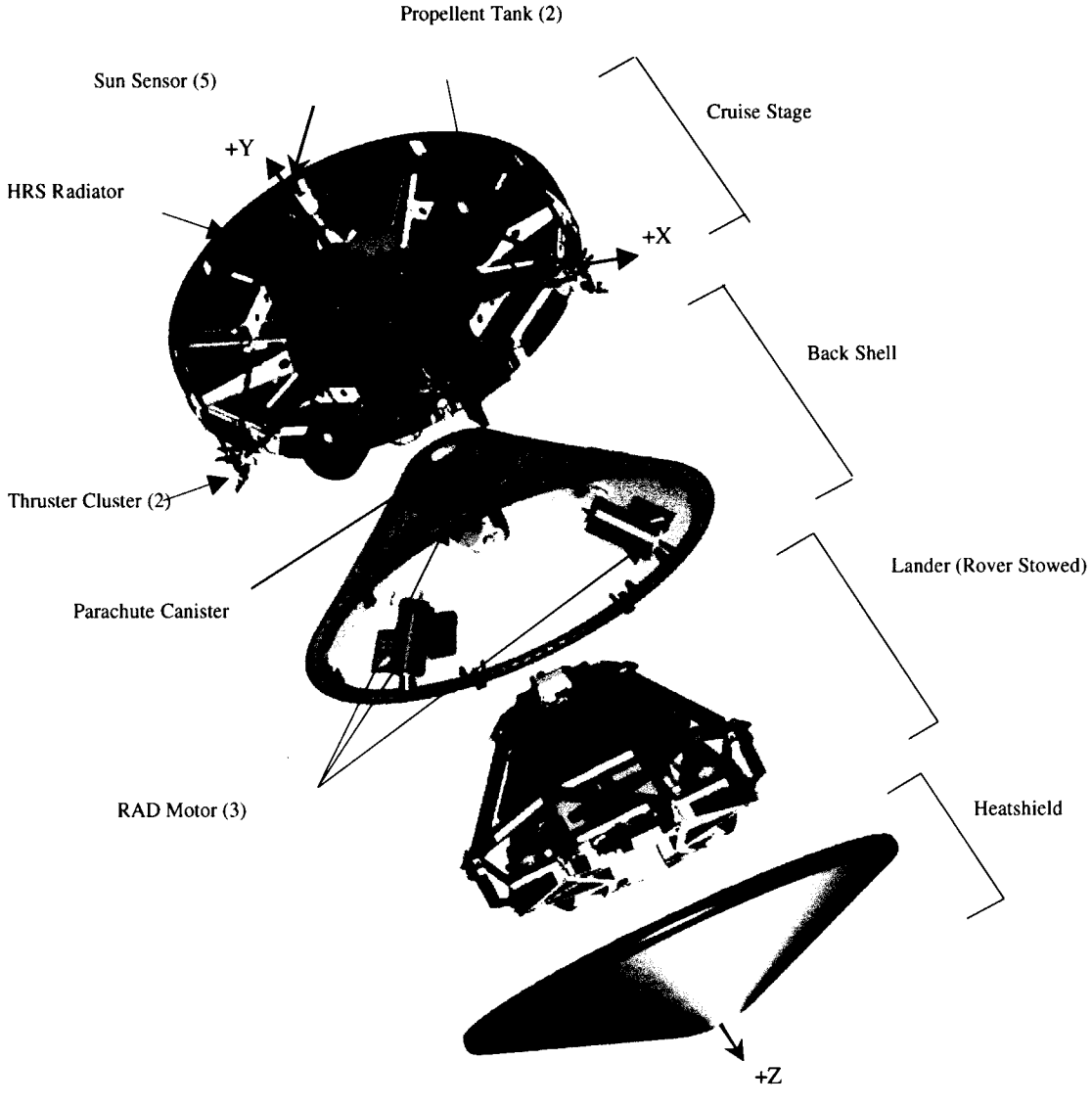
MER Configuration

Mars Exploration Rover



MER Configuration

Mars Exploration Rover



Cruise

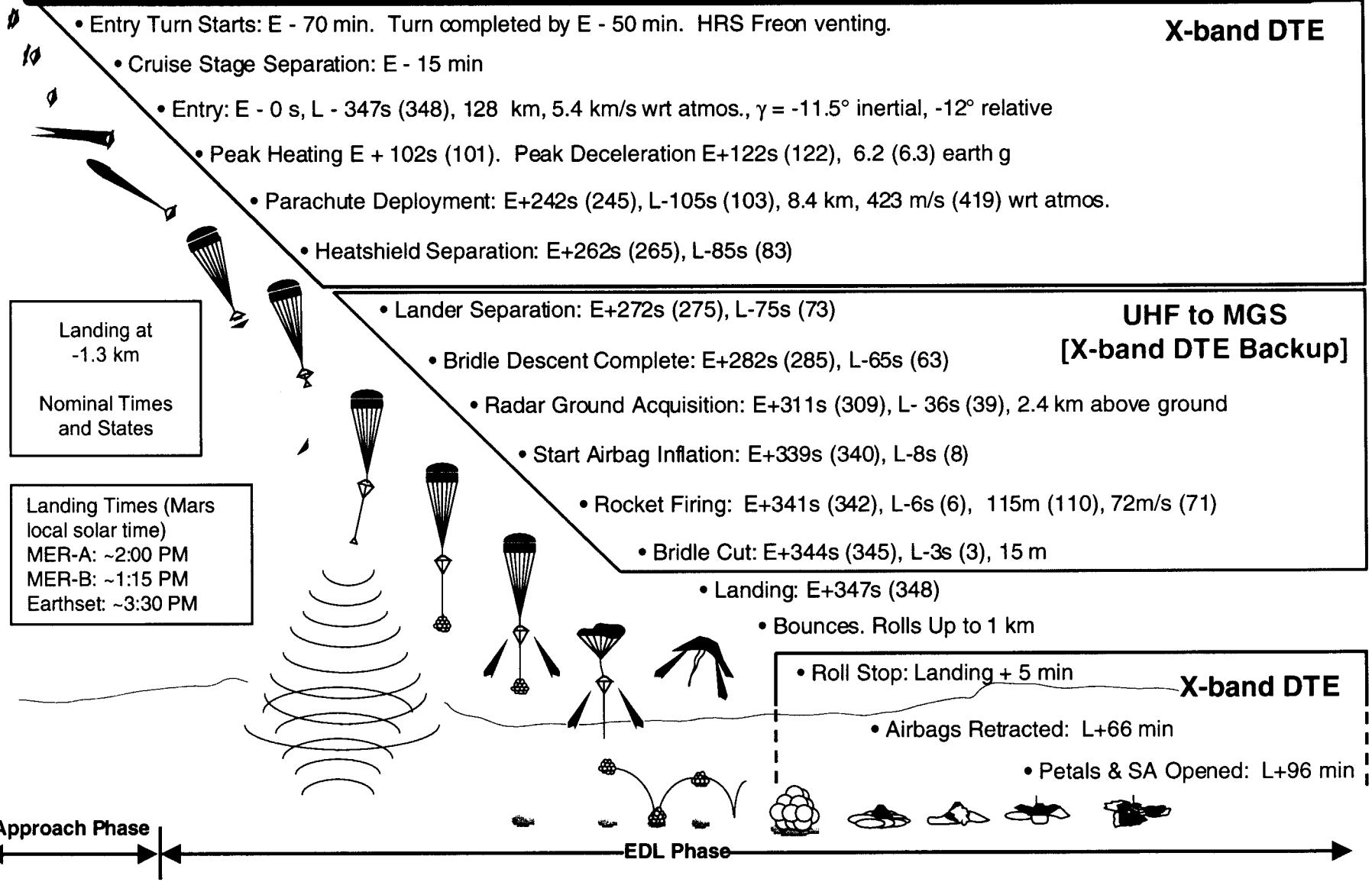
- **Cruise Phase**
  - **Post-Launch Spacecraft Checkout / Calibration**
  - **Trajectory Correction Maneuvers (TCMs)**
    - **TCM-1 (L + 15 days), TCM-2 (L + ~60 days), TCM-3 (E - ~60 days)**
      - **TCM-2 and TCM-3 timing may be adjusted to better fit within Cruise Phase activity timeline.**
  - **Science / Instrument Checkout**
    - **Reference (dark-field) images for cameras (Pancam, MI, Hazcams, and Navcams), reference spectra for APXS/Mössbauer/Mini-TES, plus engineering health data (in early and late cruise).**
  - **ACS / Navigation Calibration and Characterization and ΔVLBI performance tests.**
    - **Tests to calibrate non-gravitational trajectory perturbations due to ACS events (e.g. spacecraft turns) in early cruise.**
    - **Tests of acquisition of complementary navigation data type (ΔDOR) in early cruise and late cruise.**
  - **EDL M-FSK Tone Tests**
    - **Telecom tests performed in early cruise (near Earth) and again in late cruise (larger Earth range).**
  - **Spacecraft Attitude Adjustments to Maintain Earth/Sun Pointing**
    - **Performed periodically (10-15 times) throughout the Cruise and Approach Phases.**

Approach

- **Approach Phase (begins at Entry - 45 days)**
  - **Trajectory Correction Maneuvers (TCMs)**
    - **TCM-4 (E+ ~10 days), TCM-5 (E - 12 hours)**
      - **TCM-4 and TCM-5 timing may be adjusted to improve delivery accuracy or mission robustness.**
- **EDL preparation**
  - **Generate, validate and load communication windows through the mission**
  - **Load pre-tested, pre-validated airbag pre-heat sequences**
  - **Load pre-tested, pre-validated nominal sequences for Sol 1-5**
  - **Initiate EDL behavior**
  - **EDL parameter updates**
  - **Turn to Entry**
  - **HRS venting**
  - **Cruise stage separation**

MER EDL Timeline

Mars Exploration Rover



Impact to Egress Activities

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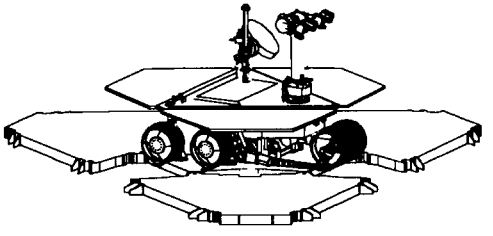
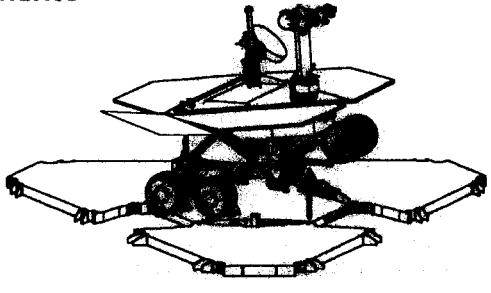
Airbag Retraction / Petal Deploy / Egress Aid Deploy

Sol 1 - Solar Array Deploy
PMA Deploy & Imaging
HGA Deploy

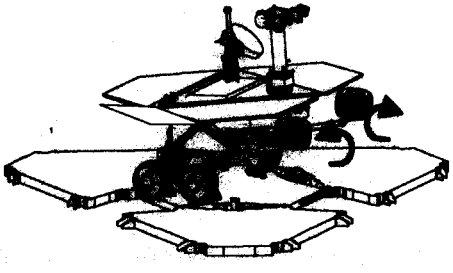


Sol 2-4
Petal / Airbag Adjustments
Pancam/Mini-TES

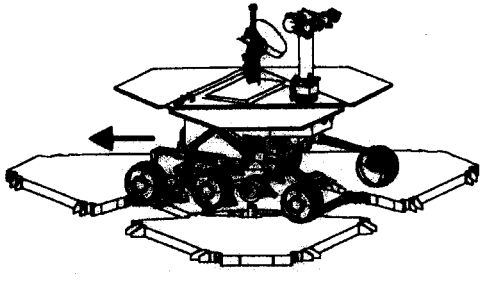
Lift Rover / Lock Rockers



Deploy Rockers



Lower Lift Mechanism & Deploy Bogies



Sol 4-5

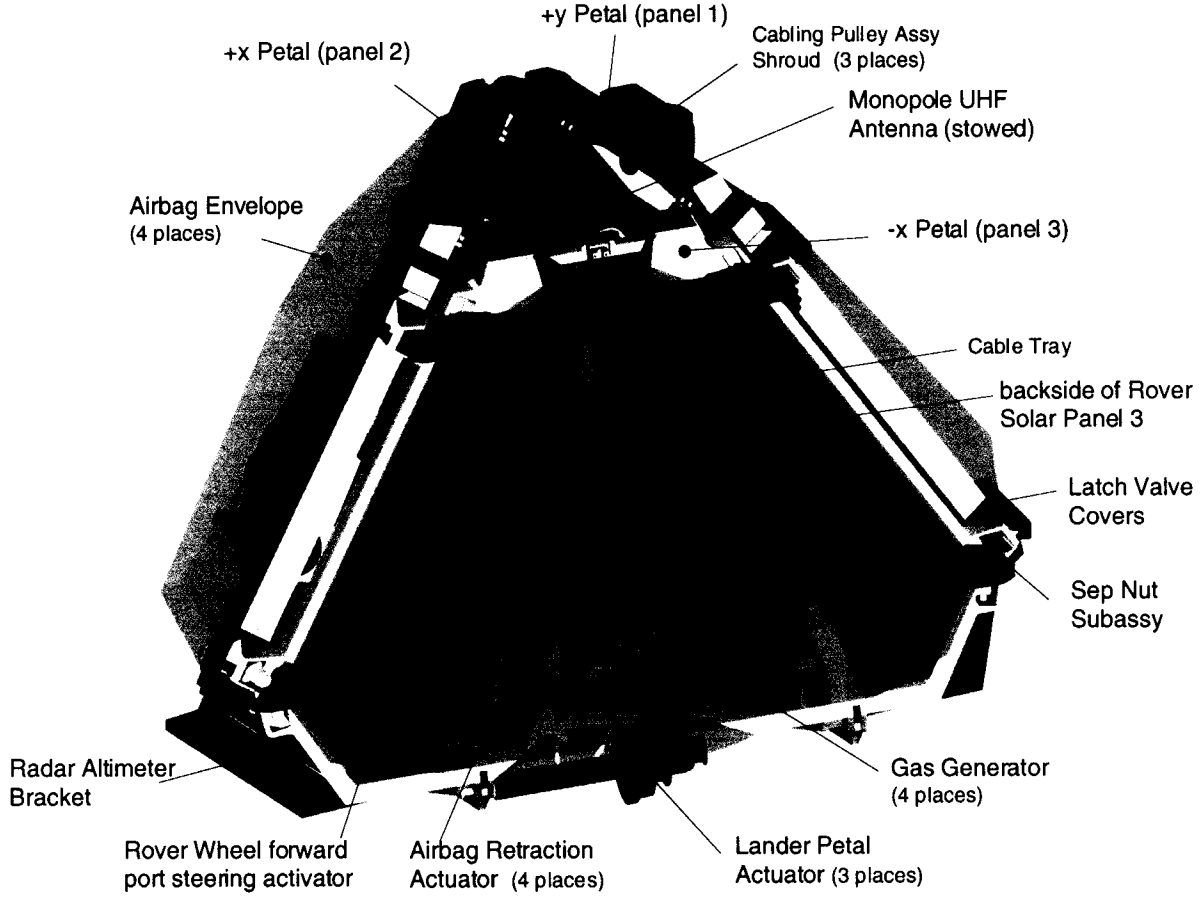
Drive Petals to final Configuration

Release Middle Wheels & Fire 3rd Cable Cutter

Turn in Place

Drive Off Lander Deck

Lander Stowed



Lander Deployed

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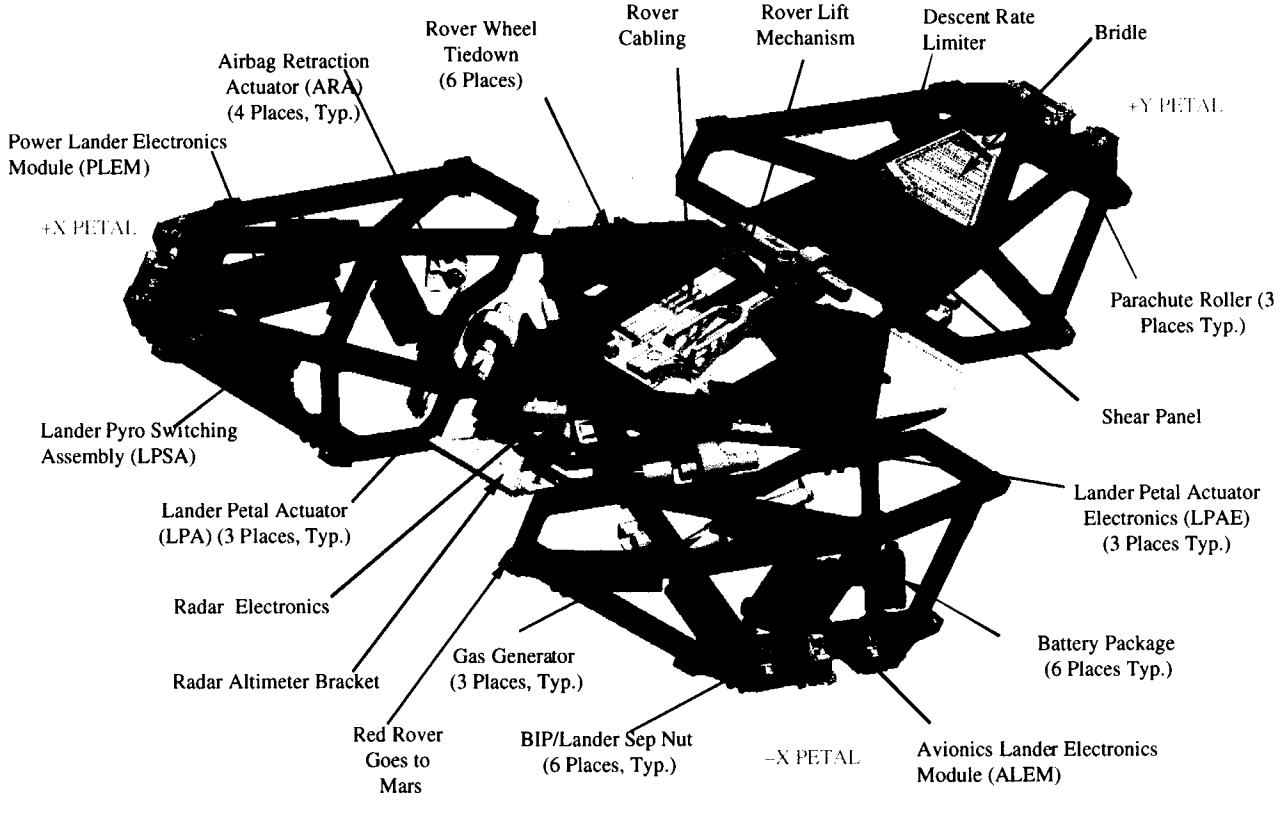
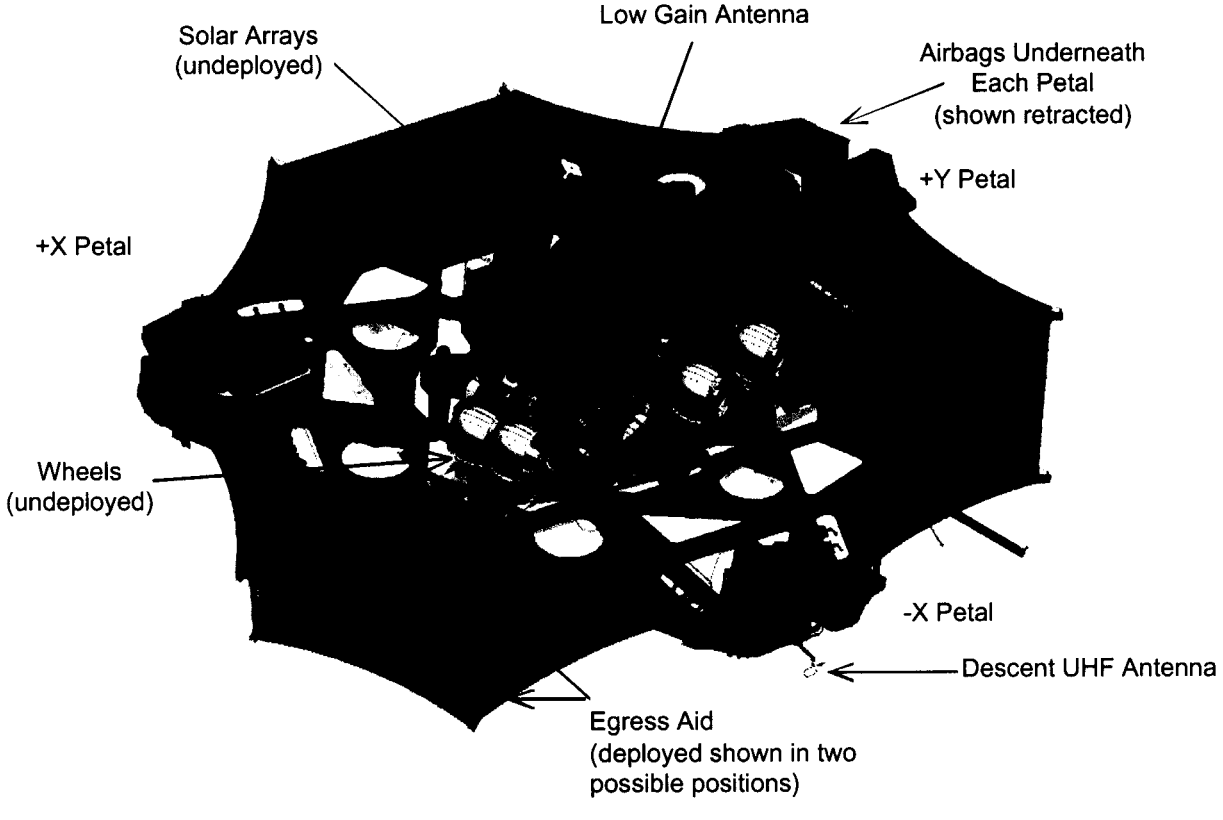
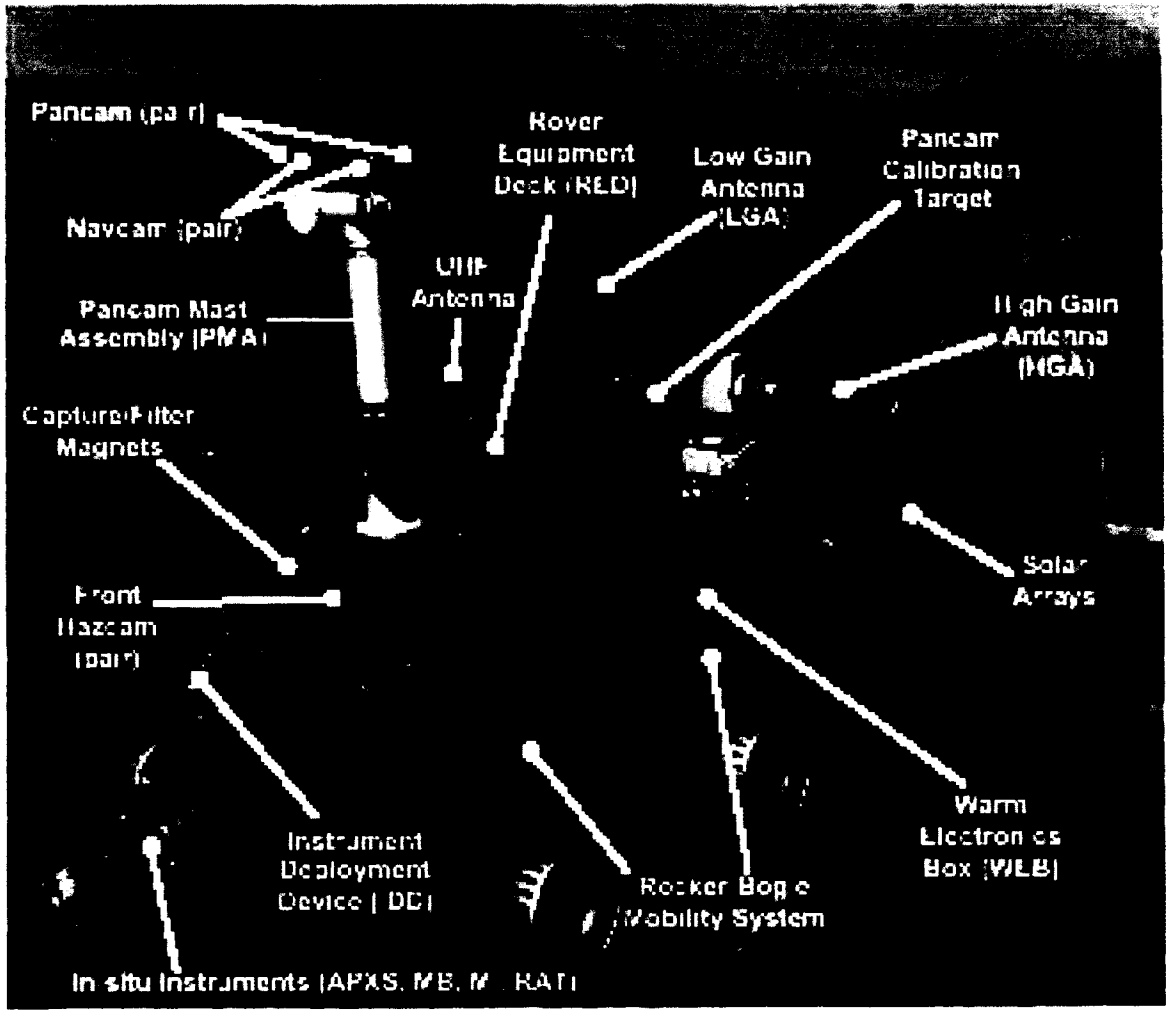


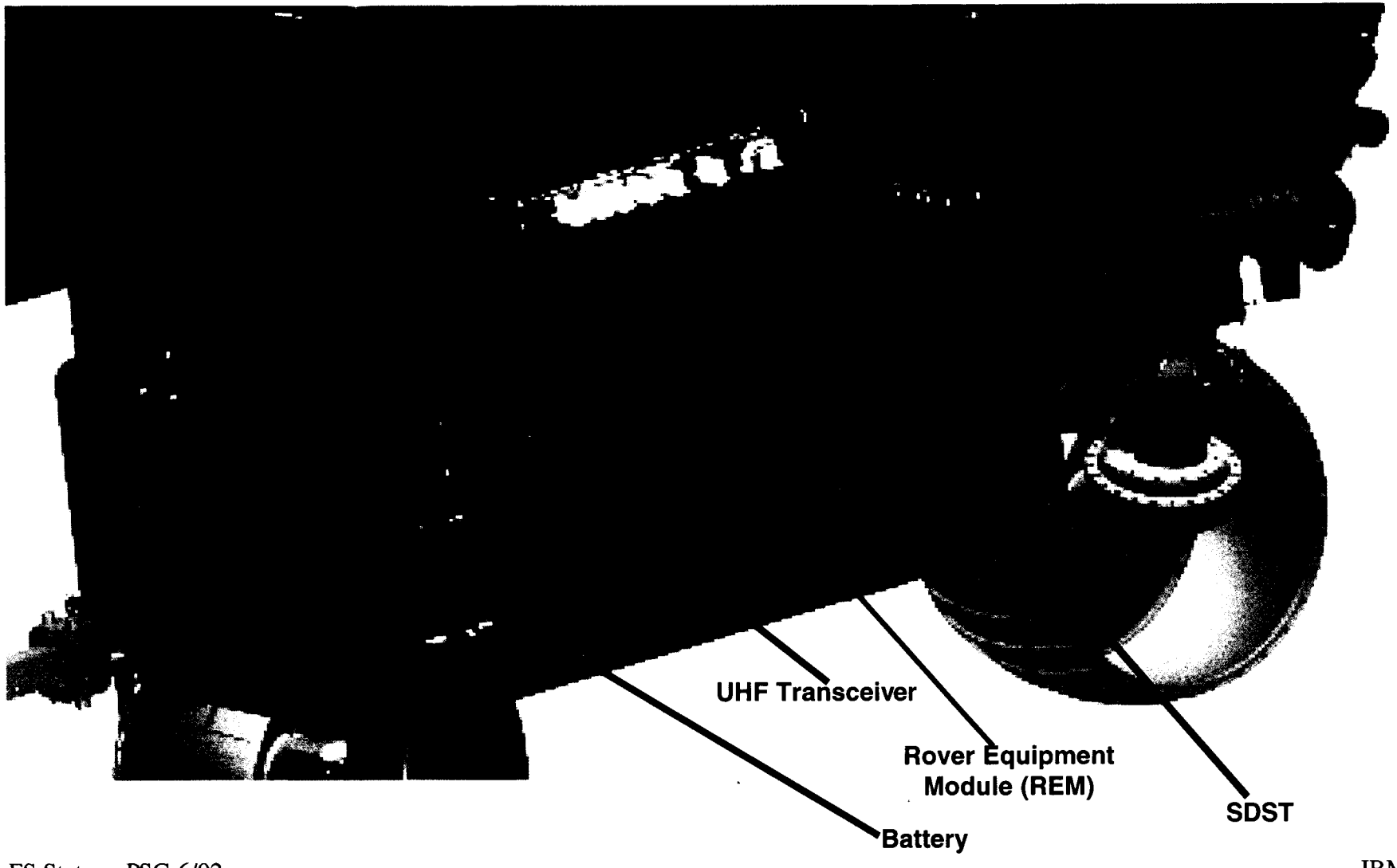
Rover Before Deployment



Rover Deployed



Rover WEB Cut Away



Changes Since Last PSG

- Cruise Stage
  - Titanium vs. Composite propulsion tanks
  - Released mass margin for fuel for TCM1 targeting of landing site(s)
- Lander
  - Removed redundant radar
  - Retained only one (of 4) landed patch antennas (on base petal)
  - Added 3 egress aids
  - Added DIMES (proposed) to determine sustained horizontal wind factor
- Rover
  - Pancam cal target to -X solar panel and UHF antenna (monopole) on RED
  - Redesigned WEB structure providing standoff of electronics from walls
  - Removed LHP, reducing X-band xmit from 4hr to 3hr per sol
  - Changed solar array vendor, resulting in reduction from 34 to 30 strings
  - Removed Suncam; rely on Pancam for sun direction determination
  - Added redundant SSPA
  - Added 2RHUs to the REM

Changes Since Last PSG (cont'd)

- **Software:**
  - **Detailed surface system elements:**
    - **Modules defined for operating mobility and payload including cameras and motors**
    - **System components handling commands, telemetry, sequence control, communication, fault protection, mission and configuration phase transitions and task intercommunication**
    - **(Several) releases of command and telemetry dictionaries and definition of data products**
    - **System components handling switches, pyros, time, wakeup and shutdown**
  - **Detailed other phase elements:**
    - **ACS, TCMs, cruise fault protection, EDL, deployments**
- **Established testbed**
- **Began ATLO**

Example Baseline Reference Mission

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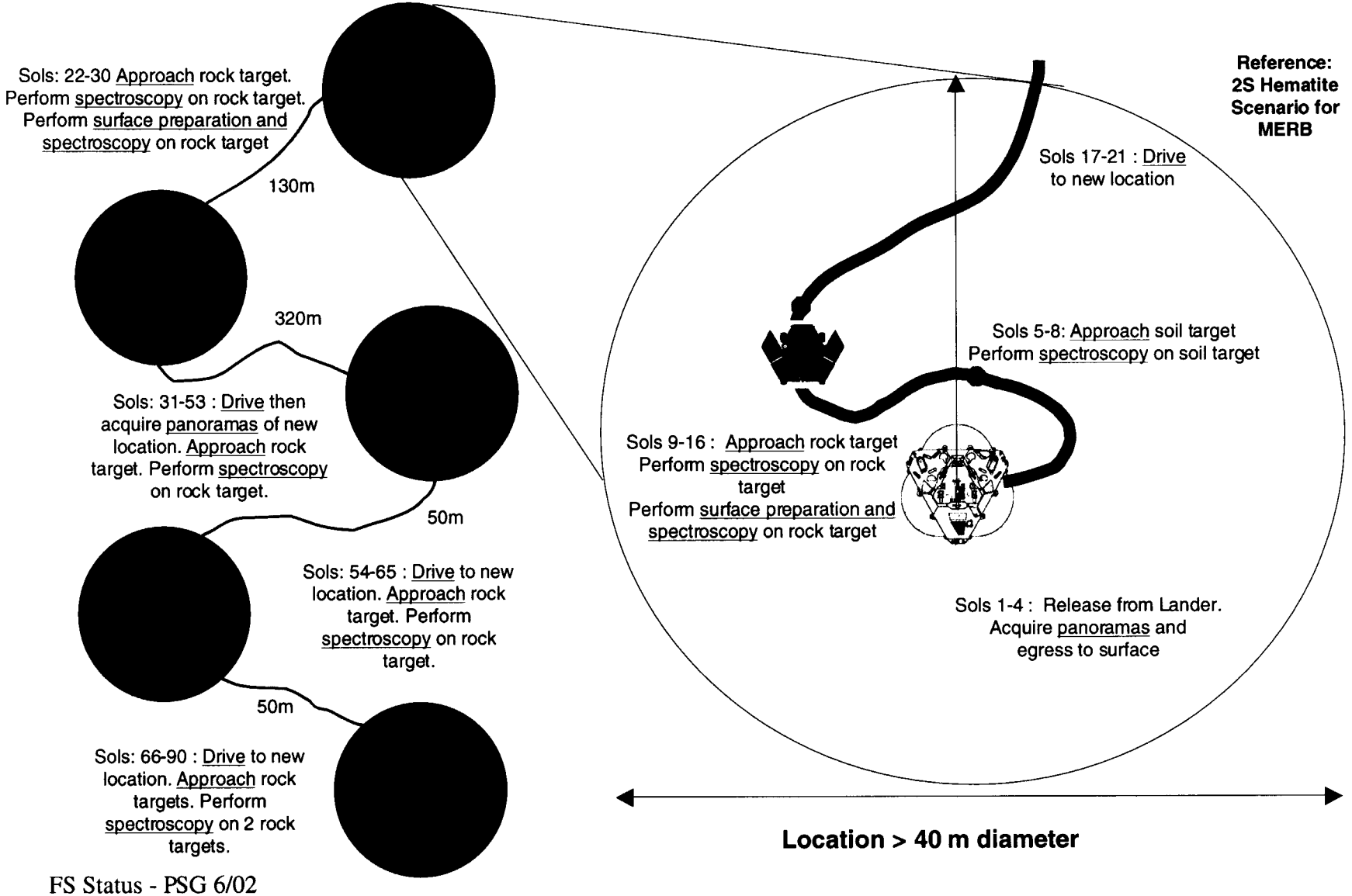
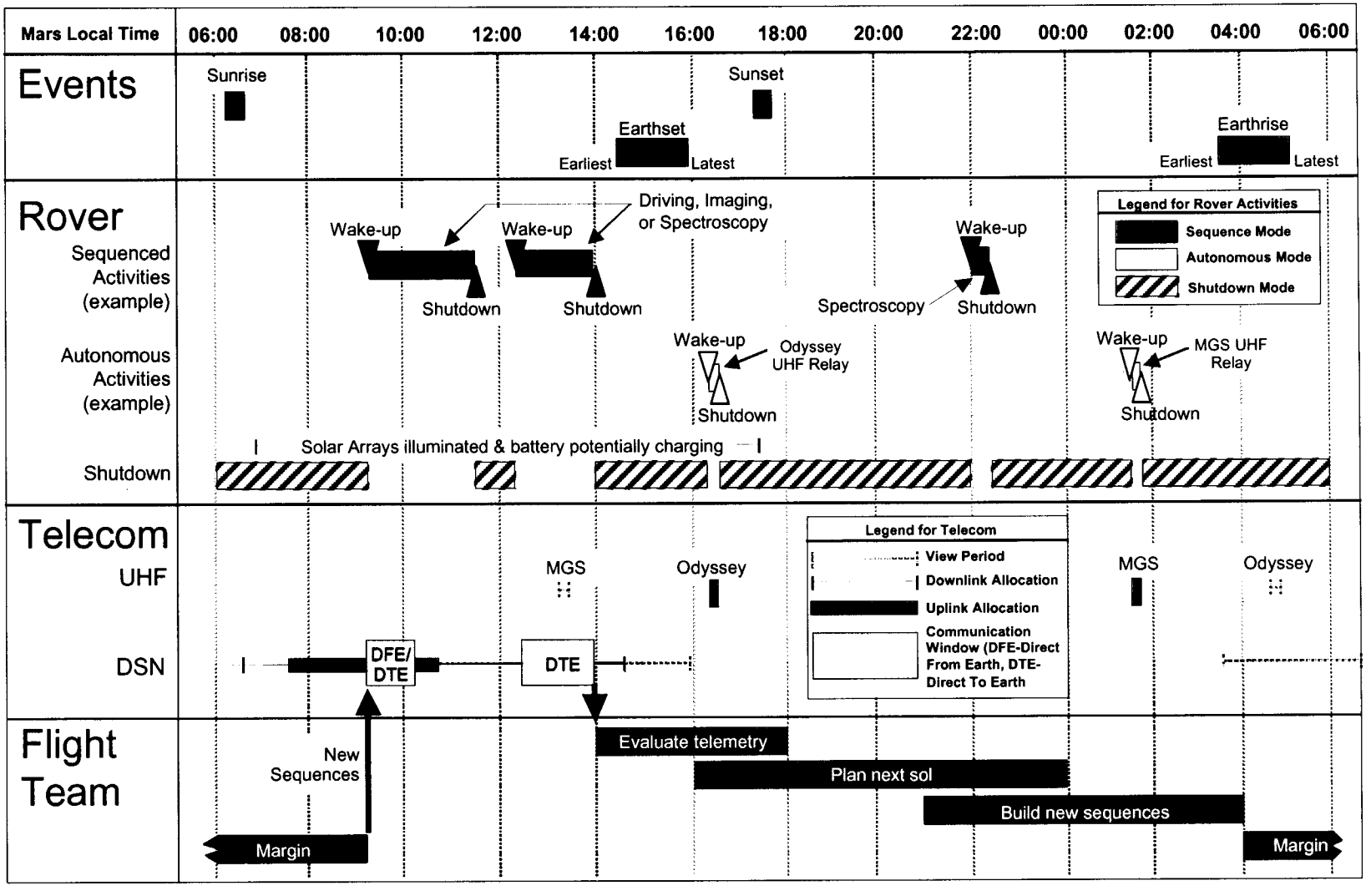


Rover Surface Sol

Mars Exploration Rover



Surface Operation

- **Automatic Actions:**
  - **Sun illuminates solar panels, energy either charges battery, is used by elements of the flight system (motors, electronics, etc.) or is shunted.**
  - **Battery charged/discharged based on voltage of the main bus**
    - **Batteries taken off-line when voltage drops below threshold**
  - **Thermal switch connects battery/RHU assembly to radiator**
  - **Thermostats control resistive heating of battery, REM, miniTES**
  - **WEB traps internal electronic energy; reflects external light/heat**
- **Autonomous Activities:**
  - **Wakeup each sol when solar panel produces sufficient current**
    - **Wakeup on alarm clock set prior to shutdown by software or command**
  - **Stay awake a few hours to receive/execute commands, transmit telemetry**
    - **Stay awake long enough to build up a thermal mass in REM (~ 3hrs)**
    - **Stay awake, at night, to perform UHF session**
    - **Stay awake to perform preparation for/commanded observation**

Surface Operation (cont'd)

- **Autonomous Activities (cont'd)**
  - **Execute sequence commands and collect telemetry**
    - **Commands generate data products and housekeeping data (EH&A)**
      - **Data products include :**
        - **images, spectra, motor operation, from payload operation**
        - **power, thermal, memory dumps, tables, parameters from engineering**
      - **EH&A sample sensor channels, component states, software parameters**
    - **Commands executed in sequence engines**
      - **Potentially one (or more) dedicated to mobility, PMA, IDD**
      - **Sequence control, wakeups/shutdowns and communication controlled in master/submaster sequences.**
  - **Resolve resource contention**
    - **Driving/steering locks out other motor operation**
    - **Can operate HGA, PMA, IDD; HGA, PMA, RAT together**
    - **Can operate PMA for Pancam or PMA for MiniTES**
    - **Images captured from one camera pair at a time**

Surface Operation (cont'd)

- **Autonomous Activities (cont'd)**
  - **Check for fault conditions**
    - **Errors in a sequence terminates that sequence activity (mobility, PMA, IDD)**
    - **Overheating, battery off-line terminate all sequences and triggers low power state**
  - **Return from low power state**
    - **Allow battery(ies) to recharge and wakeup late next sol to allow ground to initiate recovery actions**
  - **Coordinate actions:**
    - **Track with HGA to perform X-band transmission**
    - **Acquire sun direction, update attitude and position**
    - **Drive/steer the rover**
    - **Deploy/stow the IDD; acquire MI set; operate RAT**
    - **Acquire image or miniTES panoramas; Spot for sky/terrain observation**

Surface Operation (cont'd)

- **Perform sequenced activities/behaviors:**
  - **Drive safely from point A to point B**
    - **Determine attitude and position along the way**
    - **Determine hazards and plan a path to avoid hazards**
    - **Collect history data along the way**
  - **Deploy instrument on a target**
    - **Execute coordinated motion to unstow, rotate instrument in place, deploy**
    - **Move, rotate and re-deploy new instrument; stow**
  - **Acquire images/miniTES spectra**
    - **Plan PMA motion path around hardstop**
    - **Execute image/spectra acquisition over commanded range**
  - **Perform X-band transmission with HGA**
    - **Warm HGA actuators as necessary**
    - **Warm PMA actuators as necessary and then acquire sun direction**
    - **Calibrate HGA at hardstop, slew then track**
    - **Flip to continue track around hardstop**
    - **Fill during track through PMA**

Constraints for Surface Operation

Resources Available:		Constraints:
Comm Opportunities		DSN Antenna coverage
		UHF passes and latency
		Energy/Data capabilities
		25-8Mb/hr (70m)
		5-18Whr/Mb
Energy Available		(tau=0.5)
		90% of 890-580Whr (Gusev MERA)
		90% of 820-590Whr (Hematite MERB)
Energy Required for Component Survival		(Tau=0.2)
		390-450Whr (Gusev MERA)
		410-450Whr (Hematite MERB)
Energy Available for Nighttime Operations		70% of 400Whr in batteries or 310Whr
		135-90Whr remains after engineering
Data Stored		128MB available; 13-0.1MB/sol
		(e.g., 13MB/Pancam panorama
		3MB/drive, 2MB/spot measurement
		0.1MB/in situ)
Data required for next sol of operation (I.e., critical data)		0-25Mb (drive)

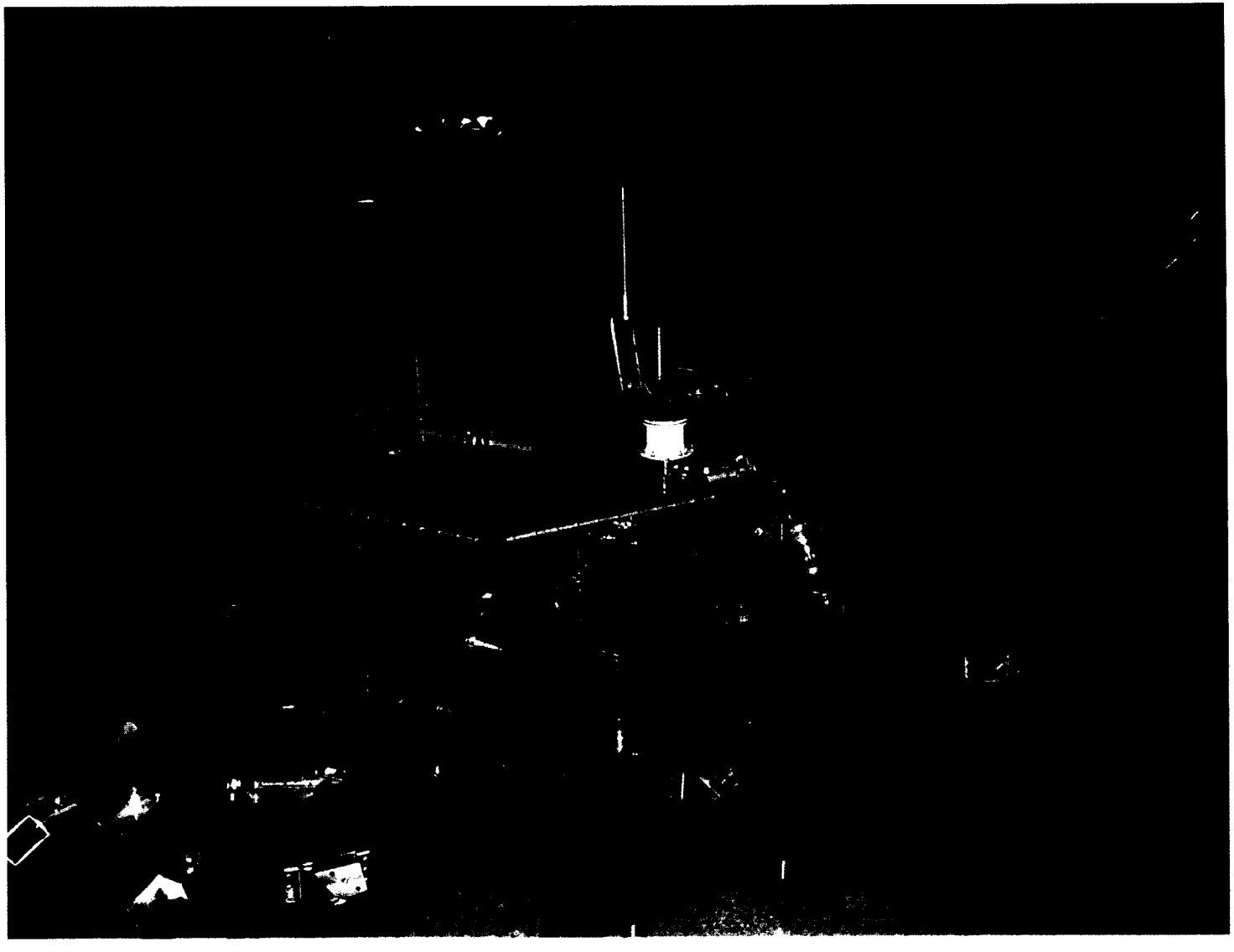
Constraints for Surface Operation (cont'd)

Resources Available:		Constraints:
Pre-heating predictions		0-50Whr (1hr)
		some times are restricted
System Health and Status:		Event report from flight software
Movements Possible:		
terrain constraints on driving		soil sinkage : 1cm of sinkage yields 4% error in distance measured
		slope slippage : 15deg of side slope yields 30% cross slip
		rock coverage : 10% coverage yields 13% added distance
Position and Orientation possible with the vehicle		10% error per distance traveled
		collision avoidance
		tilt restriction
Work envelope for IDD		Irregular workspace
		special positions for force application
Fields of view		Vehicle component obscuration
		Sun instrusion
		Shadowing

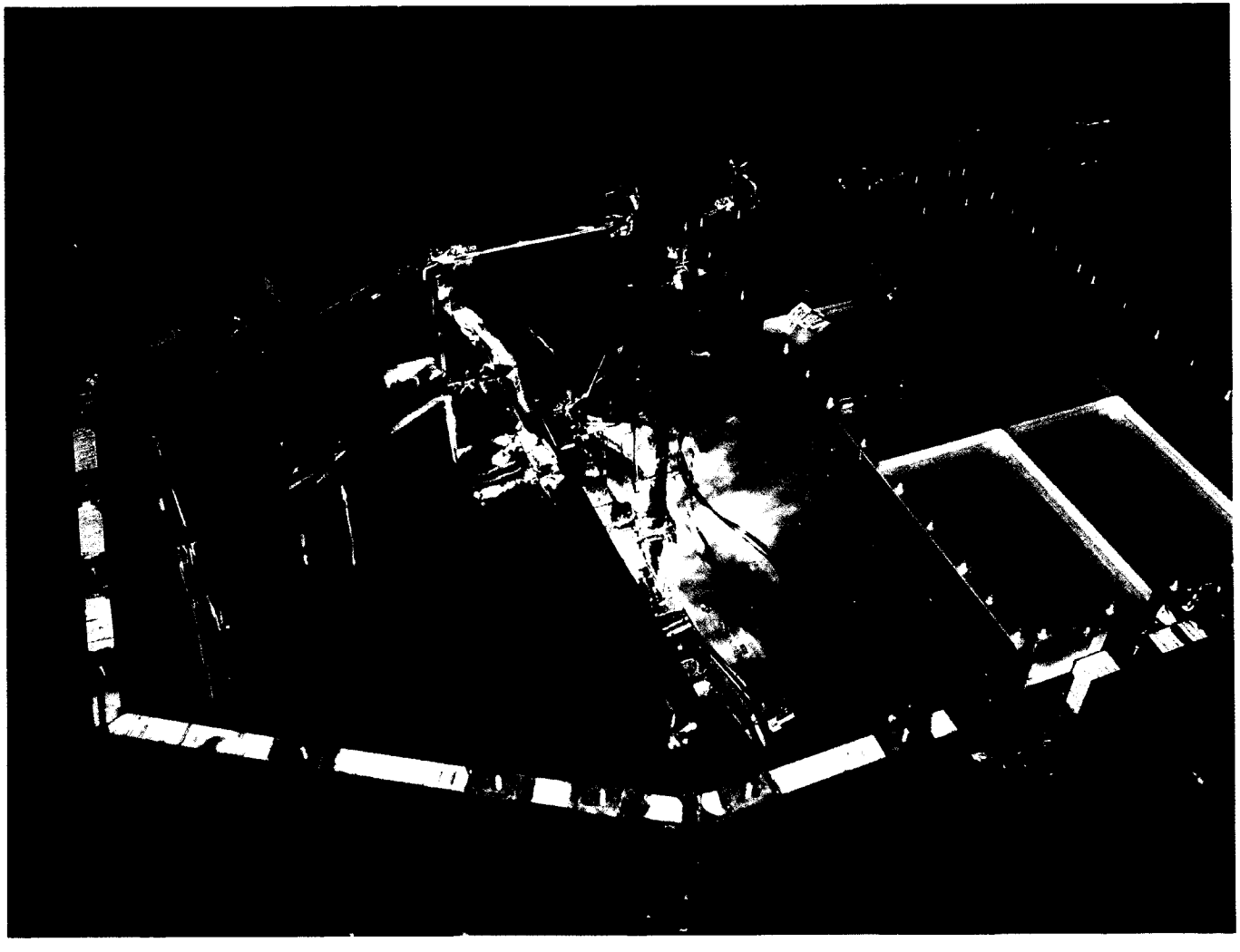
Tool set for Constraint Management

- **Constraints embodied in models:**
  - **APGEN for resources**
  - **Power, Thermal detailed models**
  - **RSVP for geometry**
- **Flight rules :**
  - **Heating times**
  - **Simultaneous operations allowed**
  - **Simultaneous operation constraints**
    - **MiniTES and RAT**
    - **Moessbauer and HGA (possible)**

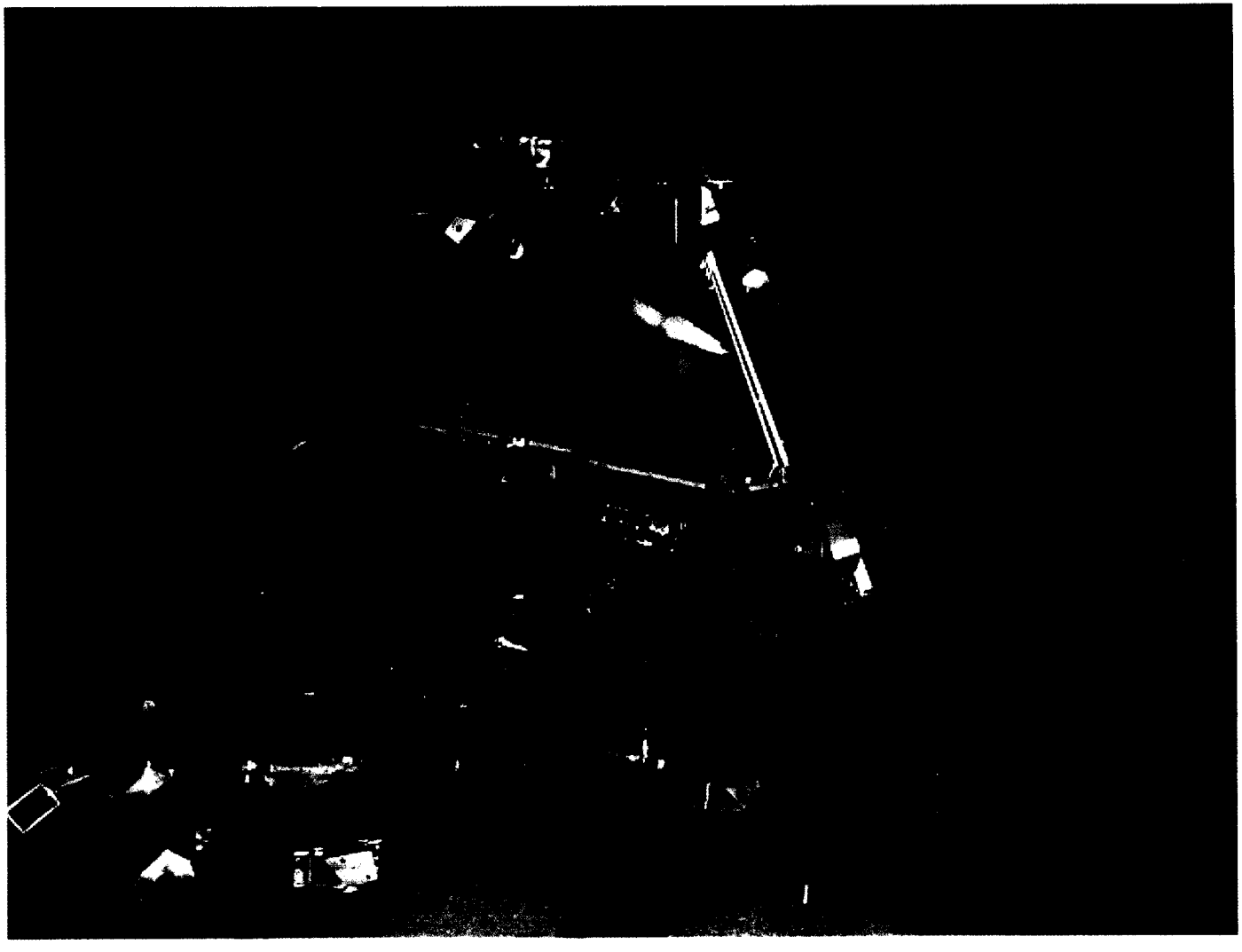
Rover on lander in ATLO



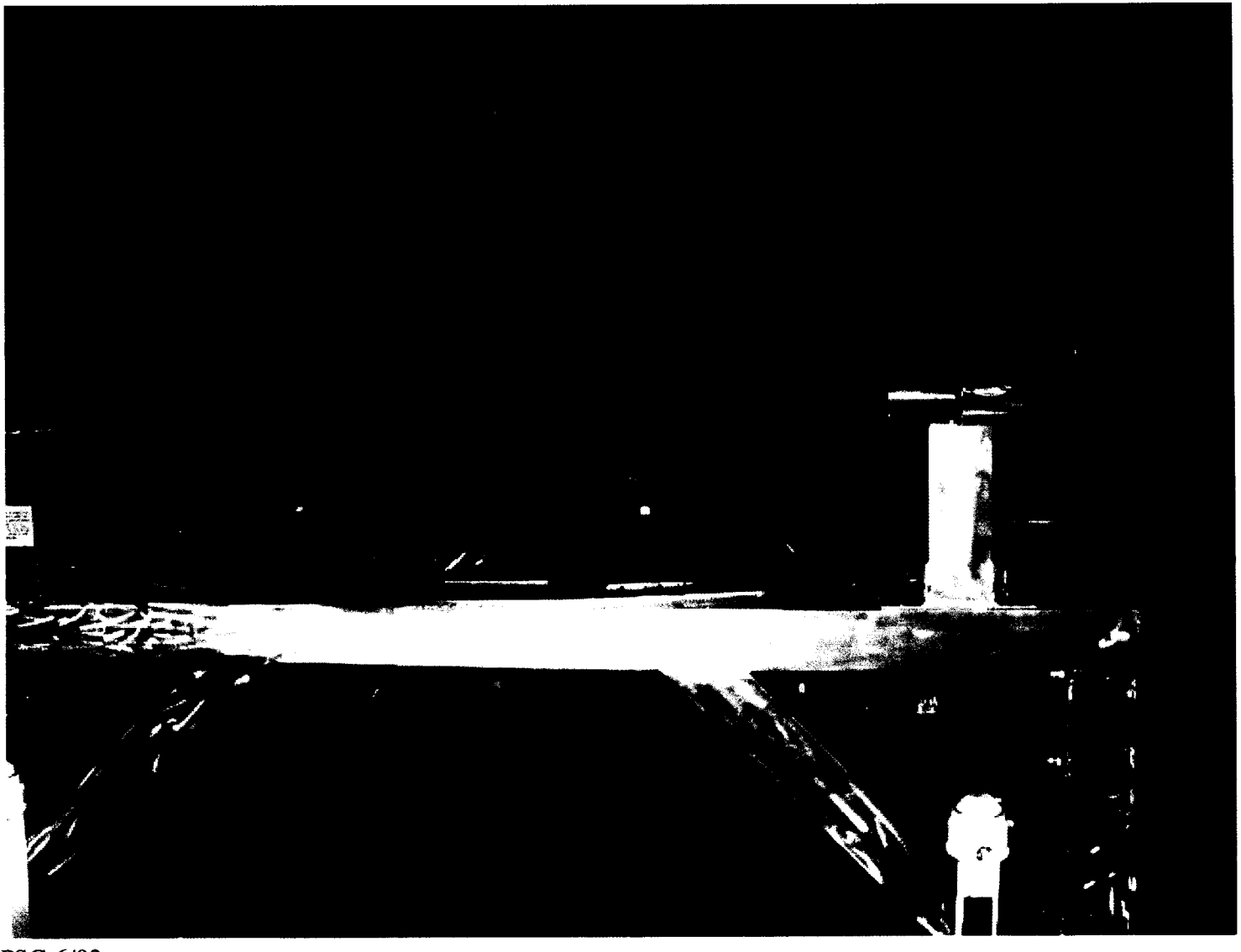
WEB in ATLO



Rover Stowed in Lander



Lander Stowed in Backshell



Vehicles

- 4 vehicles build during MER program
  - MERA, MERB are the flight rovers
  - SSTB, the Surface System Testbed, is a mobile rover accommodating models of the 'appendages' : PMA, HGA, IDD, LGA
    - Primarily used in ISIL test area for integrated payload and engineering tests
    - Main training vehicle for ORTs
  - SSTB-lite is a mobile rover with Hazcams and (possibly) a mast with a movable Navcam pair
    - Primarily used for navigation and mobility testing is ISIL test area and field tests
    - Additional training vehicle particularly used in dual mission ORTs
- Other testbeds
  - CETB, cruise/EDL testbed, is a rack-mounted system for software test and verification
  - FSWTB, flight software testbed, is a rack-mounted system for software development

Post-ship Testbed Schedule

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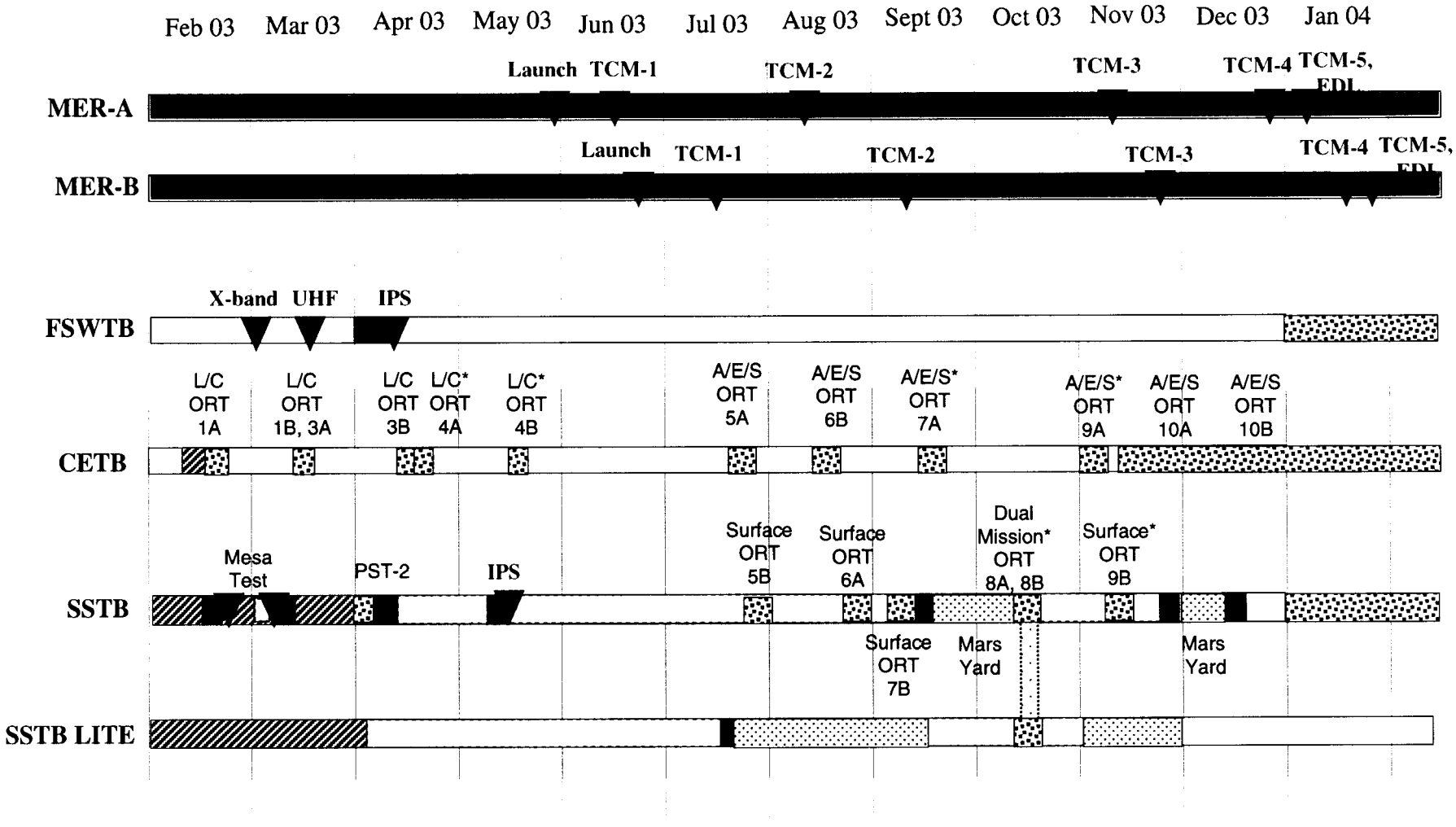

Integrated Release Schedule

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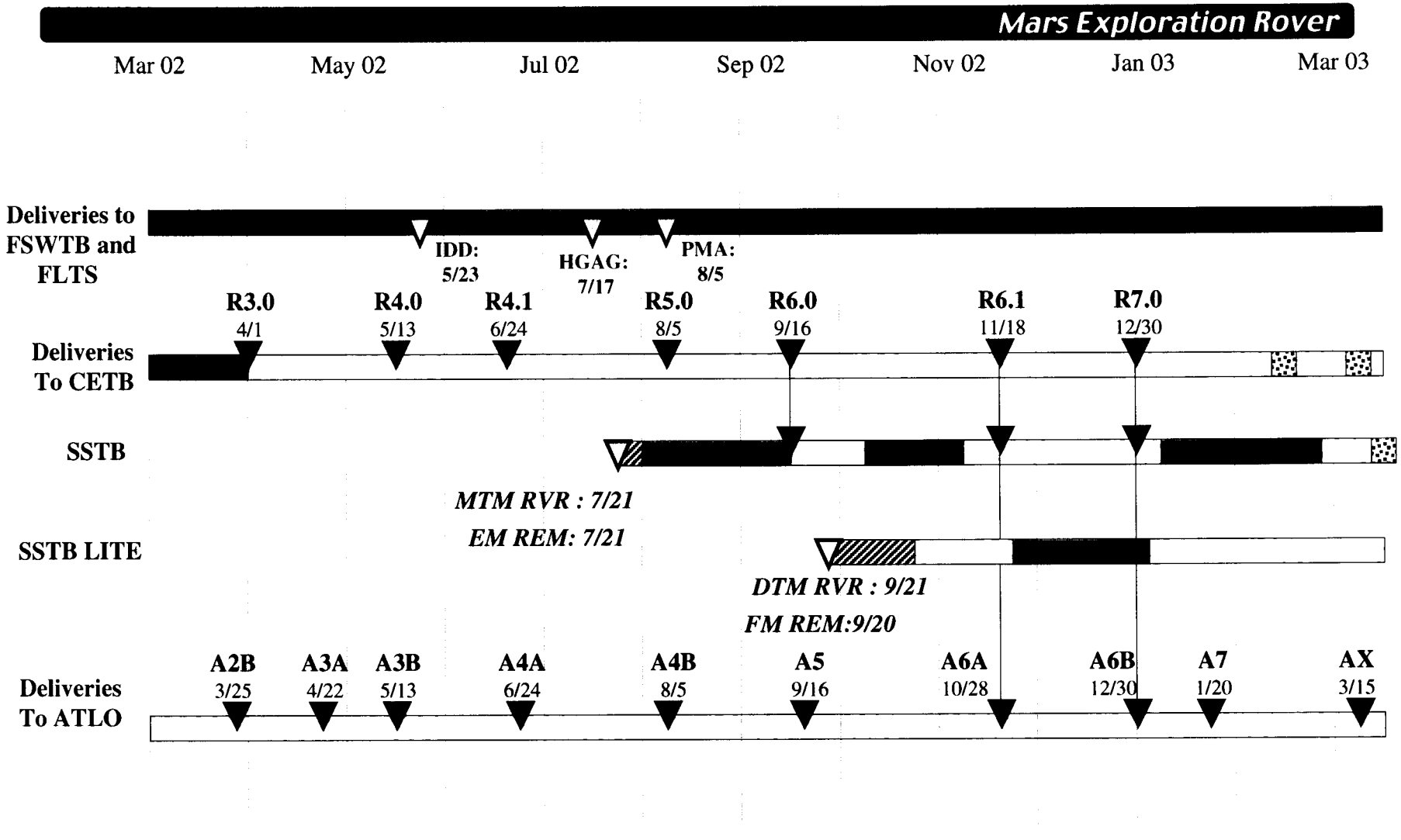

BACKUP

Launch Phase Activites

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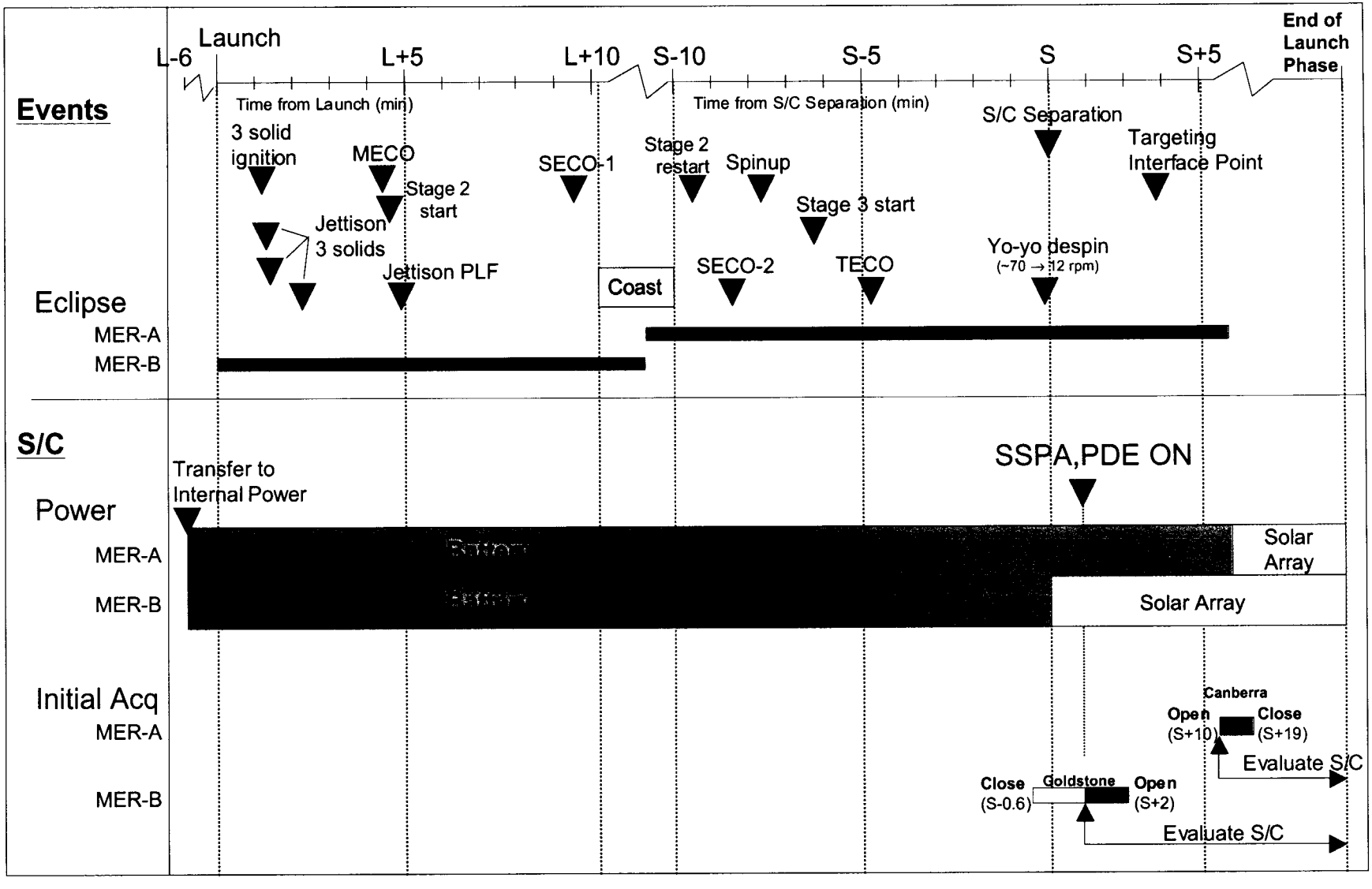

Mission Plan

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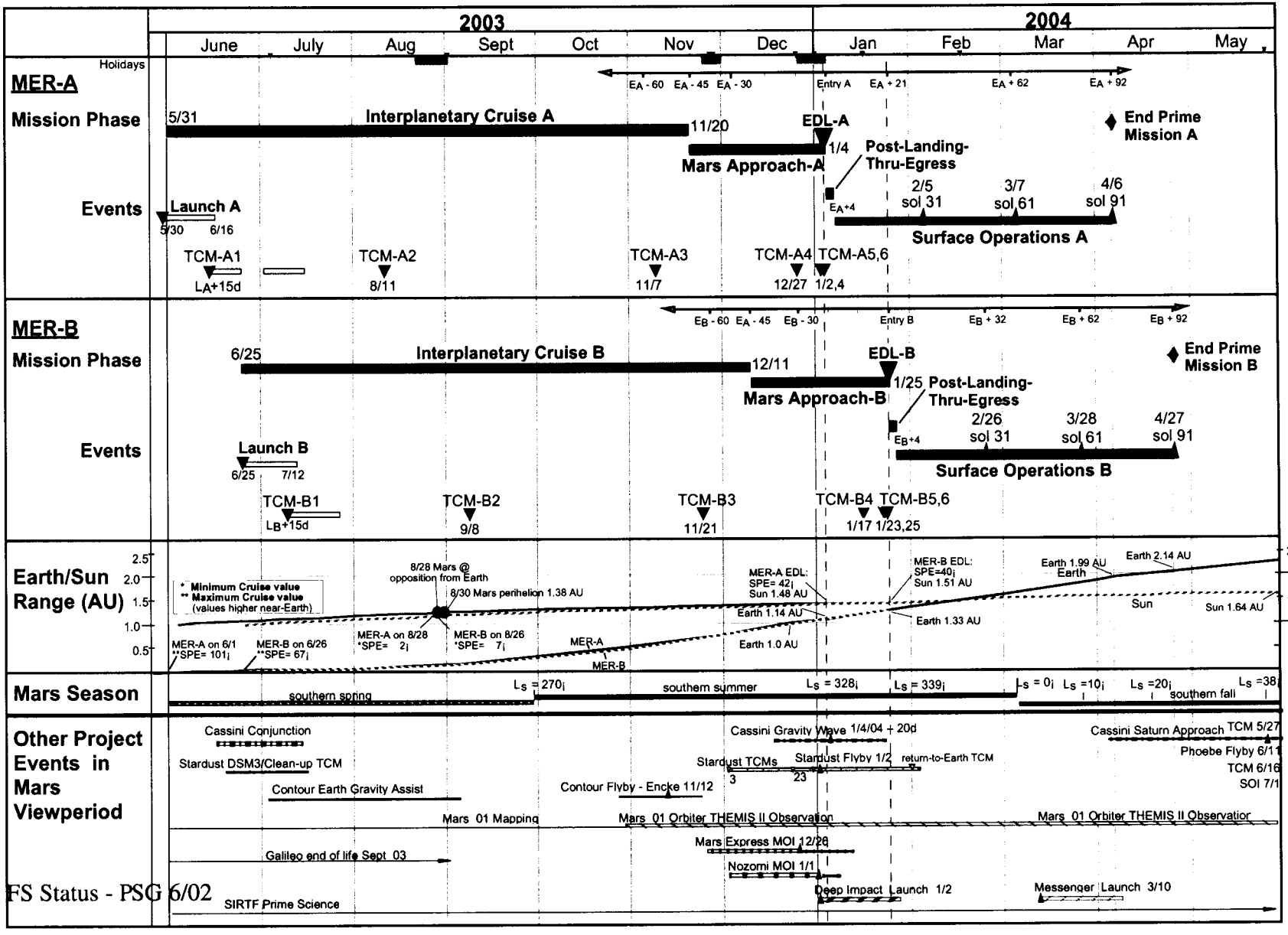

MER System

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